# Four Decades of Environmental Change and Their Influence upon Native Wildlife and Fish on the Mid-Columbia River, Washington, USA

by

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## THE HANFORD REACH: A HISTORICAL VIEW

The Columbia River originates in the mountains of sparsely-populated eastern British Columbia, Canada, and flows southwards into the United States before entering the Pacific Ocean after passing through sparsely-populated, semi-arid eastern Washington (Fig. 1). For much of its way through eastern Washington, the River passes between steep-walled canyons. However, for about 80 km downstream from Priest Rapids Dam (Fig. 2) to the town of Richland, the land has relatively little vertical relief. This is the only part of the River that is not impounded by a dam, and it is known locally as the Hanford Reach.

Before neo-European settlers began to develop the land of eastern Washington in the mid-1800s for agricultural purposes, the native upland vegetation was dominated by short-statured desert shrubs—especially Big Sagebrush (*Artemisia tridentata* Nutt.) and perennial bunchgrasses such as Sandberg Bluegrass (*Poa sandbergii* Vasey) and Bluebunch Wheatgrass (*Agropyron spicatum* [Pursh] Scribn. & Smith) (Daubenmire, 1970). However, the native vegetation has been dramatically altered by the expansion of cultivated agriculture and years of livestock grazing.

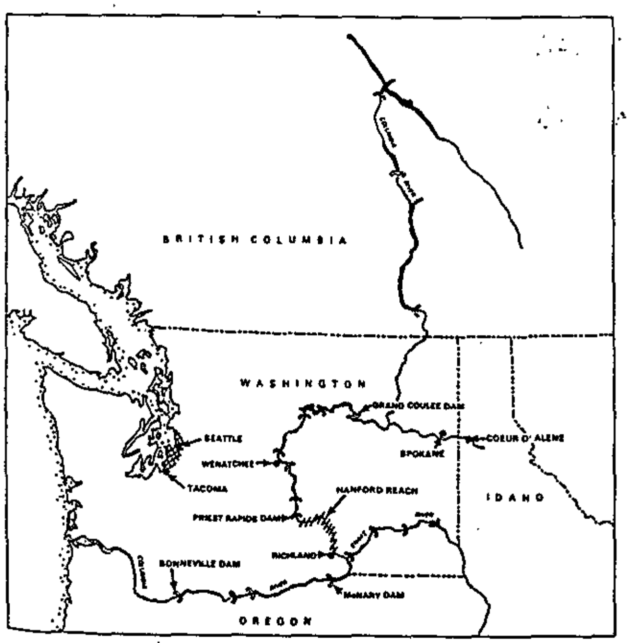


FIG. 1. *Map of the Columbia River showing the location of the Hanford Reach in relation to hydroelectric dams along the main-stem Columbia River in Washington, Oregon, and British Columbia. Scale indicated by east–west distance across centre of Washington being 530 km.*

The wildlife and the fisheries resources of the Hanford Reach attracted little scientific inquiry until the early 1940s, when 1,400 km$^2$ of semi-arid land was purchased by the United States Government as a site to construct several plutonium-production reactors. During reactor operations in the years 1943–72, heated water, corrosive chemicals, and radionuclides, were released into the River on a more or less continuous basis.

To determine the effects of radioactivity upon river fishes, various kinds of laboratory and field studies were initiated (Davis & Foster, 1958; Foster, 1972). Special attention was focused on the welfare of the commercially valuable Chinook Salmon (*Oncorhynchus tshawytscha*) and the recreationally valuable Smallmouth Bass (*Micropterus dolemieui*) (Henderson & Foster, 1957). Waterfowl, especially a locally-nesting race of the Canada Goose (*Branta canadensis moffitti*), were also selected for intensive study (Hanson & Eberhardt, 1971). Aside from radiological surveillance of Black-tailed Hares (*Lepus californicus*) for radioactive iodine-131, little attention was paid to the terrestrial biota of the Hanford Site (Hanson, 1960).

The major Man-imposed environmental changes along the Hanford Reach of the Columbia River and adjacent land during the 40-years' period of 1940 to 1980 are summarized below:

1941–50: The 1,400 km$^2$ Hanford Site was established in 1943. In the first decade, 1941–50, the small villages of White Bluffs and Hanford, located on the western shore of the Columbia River, were abandoned and the entire population was relocated. Several hundred hectares of irrigated fields and orchards surrounding the villages were also abandoned. A work-force of about 50,000 persons was temporarily assembled at the Hanford village site to construct plutonium-production reactors at four locations on the western shore (right bank) of the Columbia River.

Public access to the Columbia River and the Hanford Site land was restricted for safety and security purposes. When the production reactors became

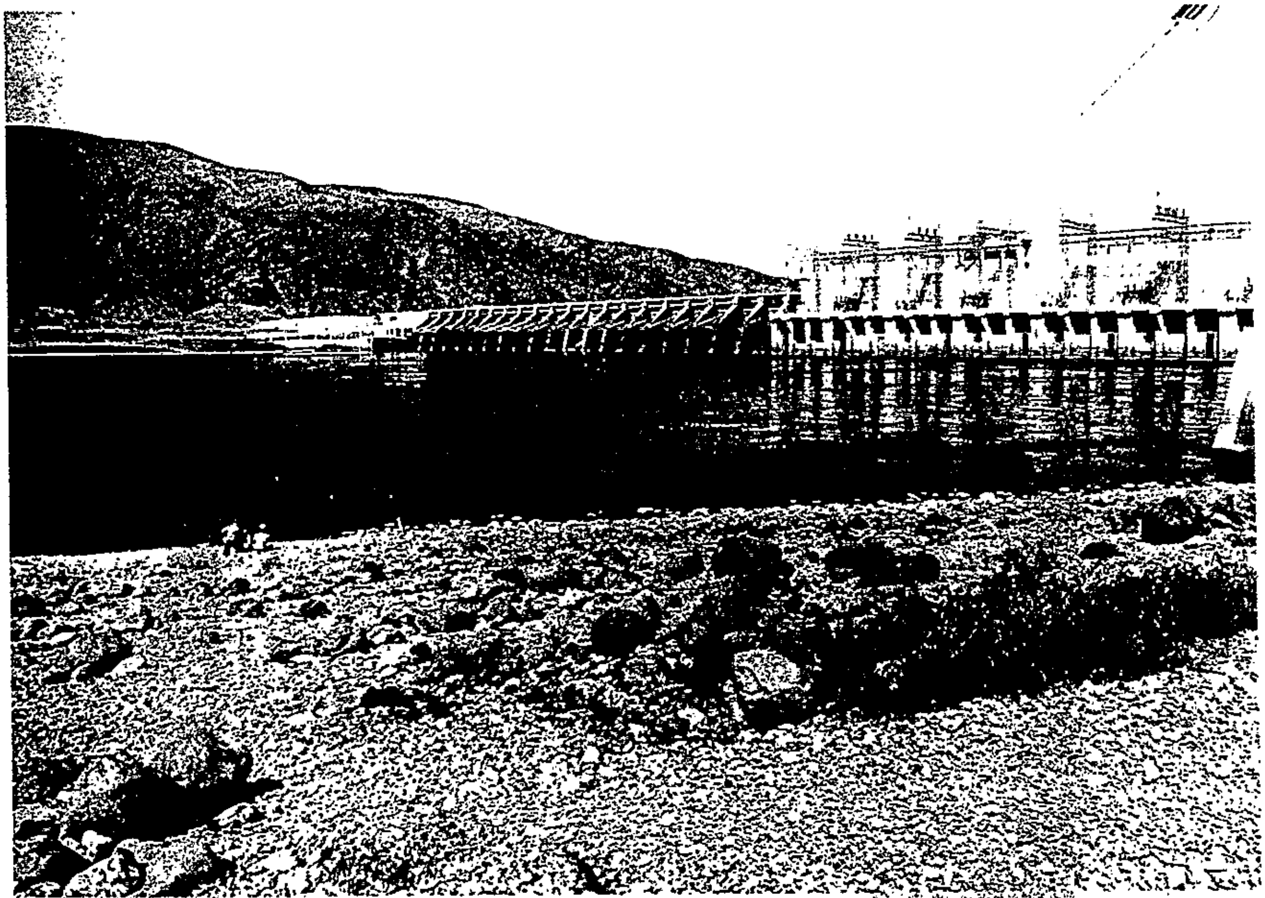

*FIG. 2. Photograph of the downstream face of Priest Rapids Dam above the upstream end of the Hanford Reach of the Columbia River in semi-arid interior Washington, USA. Fishermen are fishing for Chinook Salmon and Steelhead Trout. The view is westwards across the River. See also* Fig. 3.

operational, the temporary work-camp at Hanford village was abandoned, and a permanent work-force was housed at the town of Richland (Fig. 3). There has been no resident human population on the Hanford Site since 1943. The operating reactors released heated water, radionuclides, and corrosion-inhibiting chemicals, directly into the Columbia River, and so biological studies were initiated to determine the effects of reactor effluent releases especially on Columbia River fishes.

1951–60: In this second decade the operating reactors released a maximum of nearly 24,000 megawatts of heat, and several thousand curies of radionuclides, into the Columbia River each day. McNary Dam, located far downstream from Richland, was completed in 1953 (Fig. 3). The reservoir ('Lake Wallula'), which was thus created upstream from McNary Dam, extended to Richland. The US Bureau of Reclamation constructed the Potholes and Scooteney Reservoirs north-east of the Hanford Site, using water taken from the mainstream Columbia at Grand Coulee Dam (cf. Fig. 1).

An extensive system of irrigation canals was built to deliver irrigation water to thousands of square kilometres of semi-arid land located on the high plains to the north and east of the Hanford Site. Some of the water stored in these reservoirs and applied to fields as irrigation water, became subterranean and reappeared as permanent spring-flows in the water-bearing strata of the riverine bluffs located along the eastern shore of the Columbia River near Ringold (Fig. 3). The value of these steady water-flows was recognized, and they were developed to provide rearing-ponds for Chinook Salmon and Steelhead Trout (*Salmo gairdneri*). Canals were constructed throughout the irrigated districts to collect runoff water, and the flow of these canals (wasteways) re-entered the Columbia River at two discharge points on the eastern shore of the Hanford Reach below Ringold and near Richland (Fig. 3).

Priest Rapids Dam, constructed upstream from the Hanford Site, became operational in 1959 (Fig. 2). The operation of Priest Rapids Dam and other upstream dams dramatically altered the river-flow throughout the Hanford Reach (Books, in press).

1961–70: In this third decade, the operation of plutonium-production reactors on the Hanford Site was phasing out, and radionuclide and chemical releases to the Columbia River essentially ceased. The dual-purpose (electricity and plutonium) N reactor continued to operate, releasing heat but very little Man-induced radioactivity into the River.

The technical development of electric-powered, overhead-sprinkler irrigation systems allowed the irrigation of relatively rough land, and this increased the areas of irrigated land on the plains eastward from the Hanford Site. Today the Hanford Reach persists as the only free-flowing portion of the Columbia River in

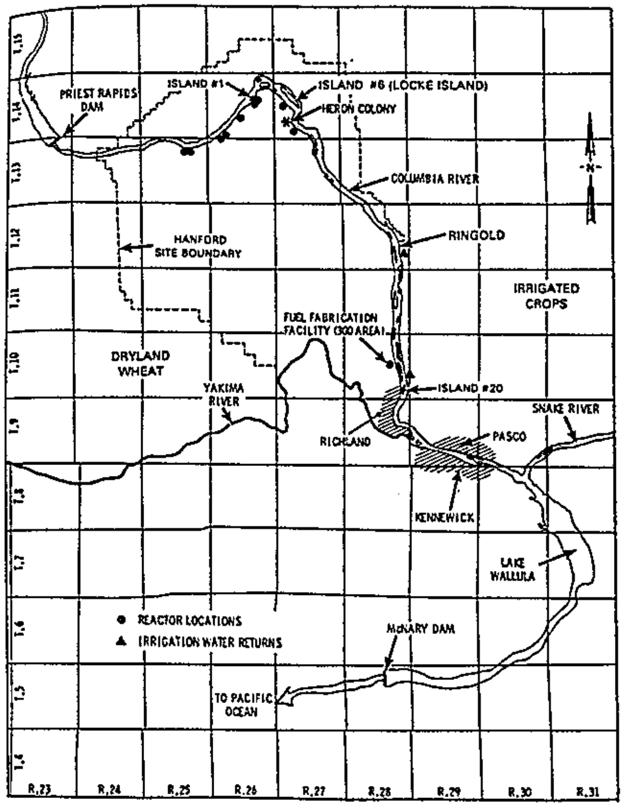


FIG. 3. *Map showing the section of the Columbia River between McNary Dam and Priest Rapids Dam, with location of the US Department of Energy's Hanford Site, riverine islands, and other features mentioned in the text. (Each square represents a 'township' of 36 miles (ca 58 km) dimensions.*

eastern Washington, as all other suitable sites have been occupied.

1971–80: On the Hanford Site the N-Reactor continues to operate, and there are being constructed three commercial, nuclear-powered, steam-electric stations inland from the Columbia River. These stations are to be equipped with cooling towers instead of requiring direct discharge of heated water into the River, as was the case of the plutonium-production reactors that had been built on the Hanford Site in earlier years. A plan to build a hydroelectric dam in the Hanford Reach upstream from Richland is being held in abeyance, as seasonal and daily flow-patterns of the Columbia River in the Hanford Reach become more and more regulated as a result of increased water-storage capacity at upstream dams in the US and in Canada.

After 25 years of restricted access, the Hanford Reach is opened for boating, but public access to the Hanford Site land west of the Columbia River is restricted. Rangelands and dryland agricultural areas surrounding the Hanford Site are steadily being converted to irrigated agriculture. New seeps and springs appear in the water-bearing strata of the riverine bluffs on the eastern shore of the Columbia River, creating massive earth-slumps that encroach on river-flow. Seep ponds and lakes are created on the northern part of the Hanford Site, as irrigation canals are extended to deliver irrigation water to dryland areas located north of the Hanford Site.

Most of the Hanford Site land remains undeveloped, and will presumably support communities of native plants into the foreseeable future. In 1977, the Hanford Site was designated a National Environmental Research Park, to be used as an outdoor laboratory for ecological research purposes—including preservation of diversity of native populations of plants and animals (cf. Rickard *et al.*, 1982).

## STATUS OF RARE, THREATENED, AND ENDANGERED, SPECIES ALONG THE HANFORD REACH

The American Bald Eagle (*Haliaeetus leucocephalus*) is listed by the US Fish and Wildlife Service as an endangered species. However, in the State of Washington, it is listed as 'threatened'. The largest congregations of wintering Bald Eagles in the State of Washington occur along the Skagit and other rivers in the northwestern part of the State (Servheen, 1975; Stalmaster *et al.*, 1979). Nevertheless, the Hanford Reach has historically attracted small numbers of Bald Eagles as winter residents (Fitzner & Hanson, 1979). In the 1960s, wintering Bald Eagles were present, but less than ten birds were censused, whereas by the 1970s, numbers had increased to twenty or more birds (Fig. 4). The increase in wintering Eagles is attributed to increasing numbers of autumn-spawning Chinook Salmon in the Hanford Reach (Fig. 4). Chinook Salmon die after spawning, and their carcasses provide a food-source for the Eagles. The continued use of the Hanford Reach by wintering Bald Eagles appears to be tied to the abundance of dead Salmon.

Two rare plants occur along the Hanford Reach of the Columbia River. One is the Columbia River Milk-vetch (*Astragalus columbianus* Barneby), which has a very limited geographic distribution only in the vicinity of Priest Rapids Dam. This vetch population is subjected to spring grazing by sheep and cattle, but appears to be in no immediate danger of extinction because of this livestock grazing (Sauer *et al.*, 1978). The plants grow in seasonally dry soils at elevations well above the zone of Man-induced water-level fluctuations of the Columbia River. The local variety of Yellow Cress (*Rorippa calycina* var. *columbiae* [Suksd.] Rollins) is also a plant of limited geographic distribution. It grows in the Hanford Reach at the water's edge within the zone of fluctuating water-levels (Sauer & Leder, in press). At the present time there are no vascular plants that are known to grow along the Hanford Reach and are classified as endangered by the US Fish and Wildlife Service.

## WILDLIFE RESOURCES

The Western Canada Goose (*Branta canadensis moffitti*) nests on twenty sparsely-vegetated, sand-and-cobble islands in the Hanford Reach (Ball *et al.*, 1982) (Fig. 3). Although the historic pattern of river-flow has been altered by flow-regulations at upstream dams, the integrity of the goose-nesting islands has not been appreciably changed (DeWaard, 1981). Over the past 30 years, these Geese have consistently favoured ten of the twenty islands as nesting habitats. In the decade 1950–60, a favoured island for nesting was Locke Island (Fig. 3). Nesting use of this island declined in the decade 1961–70, and by 1980 nesting attempts by these Geese had nearly ceased, due to the year-

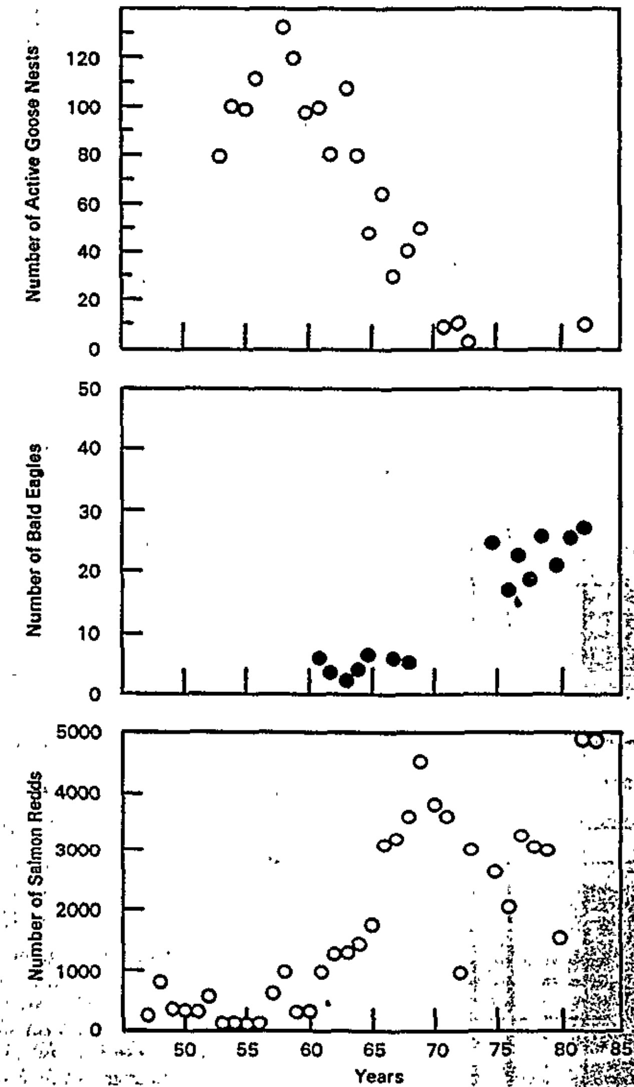


FIG. 4. *Numbers of active Goose nests on Locke Island in the years 1953–82 [Top]. Numbers of Bald Eagles wintering on the Hanford Reach in the years 1961–82 (there were no counts in the years 1969–74) [Middle]. Numbers of Salmon redds (nests) counted in the years 1947–82 [Bottom].*

around presence of a few Coyotes (*Canis latrans*) (Fitzner & Rickard, 1983).

Ring-billed Gulls (*Larus delawarensis*), California Gulls (*L. californicus*), and Forster's Terns (*Sturnella forsteri*), nest in large colonies on two islands located near the town of Richland. In 1977, *ca* 5,100 pairs of California Gulls and *ca* 4,600 pairs of Ring-billed Gulls nested on these islands (Conover *et al.*, 1979). An estimated 400 pairs of Forster's Terns also nested on these same islands (R. E. Fitzner, pers. comm.). The nesting gulls and terns benefit from the protection from human trespass provided by the US Fish and Wildlife Service, which manages these islands as bird-nesting refuges.

The Great Blue Heron (*Ardea herodias*) is a year-around resident along the Hanford Reach, and about 40 pairs nest in a small grove of deciduous trees located on the western shore of the Columbia River on the Hanford Site (Fig. 3). Over the years, the nesting Heron population has gradually increased, benefitting from the freedom from human disturbances provided by the restricted public access to the Hanford Site, by the deciduous trees planted in the years prior to Government's acquisition of the land, and by the availability of food-fish in the Columbia River.

Mule Deer (*Odocoileus hemionus*) are the largest of the wild mammals that permanently inhabit the Hanford Reach. Mule Deer were scarce along the Hanford Reach in the years prior to 1940, because they were treated as pests by the local farmers and were shot at every opportunity. The abandonment of the small farming villages of Hanford and White Bluffs in the early 1940s, and the absence of shooting on the Hanford Site in the following years, permitted the Mule Deer population to expand. Tagging studies showed that some of the fawns born on the Hanford Site left it and were killed when they moved to the adjacent lands (Hedlund, 1975; Eberhardt *et al.*, 1984). The Deer population on the Hanford Site appears to be relatively stable; there have been no population eruptions, and consequently no need to practise population control. Coyotes are known to be important predators on Mule Deer fawns (Steigers & Flinders, 1980), and apparently natural predation and emigration keep the Deer population of the Hanford Site at a stable level.

The effect of Man-induced water-level fluctuations on wild birds associated with streamside habitats along the Hanford Reach of the Columbia River has recently been investigated by Books (in press), who noted that daily exposures of mud-flats and beaches by fluctuating water-levels provided food subsidies, in the form of insects and small fishes stranded by receding water, for birds of the ground-feeding guild. The foraging activity observed during periods of receding water-level was significantly higher than would be expected by chance alone (Table I).

## FISH RESOURCES

The fish populations of the Columbia River are valuable commercial and recreational resources. Most of the local fisheries research and management has centred upon the anadromous Chinook Salmon and the Steelhead Trout. Populations of the Salmon and Trout are sustained by artificial propagation, and by protecting river-spawning fish (Watson, 1970) through a regulated sport and commercial fishery. Millions of young salmonids are released into the River each year for downstream migration to the Pacific Ocean. Upstream migration of adult fish returning to the Hanford Reach after a 2–4 years' residence in the Ocean, is accomplished by passage through fish-ladders at downstream dams—after surviving commercial, sport, and American Indian, harvests at sea and in the lower Columbia River.

An annual census of Chinook Salmon redds (nests) in the Hanford Reach has been conducted by aerial counts since 1947 (Fig. 4). These data clearly show that the Hanford Reach has consistently supported mainstream-spawning Salmon, with the greatest numbers of redds counted in recent years. The increase in redd numbers is attributed to the absence of suitable spawning locations elsewhere along the mainstream Columbia River, to a vigorous stocking

**Table I**

*Statistical Analysis of Ground-feeding Birds in Relation to Fluctuating Water-levels Along the Hanford Reach of the Columbia River.*
(Data from Books, in press.)

| *Type of Ground-feeding* | *Number of Observations* | *Percentage of Observations During Receding Water-levels* | *Chi-square Values* |
|---|---|---|---|
| Rock Pickers | 166 | 78 | 55.5[a] |
| Gravel Pickers | 250 | 87 | 135.4[a] |
| Sand Pickers | 110 | 89 | 67.2[a] |
| Mud (Silt Deposits) (Probers and Pickers) | 878 | 59 | 29.2[a] |
| Grass Pickers | 988 | 82 | 396.6[a] |
| Wading Bottom-probers | 35 | 27 | 8.3[b] |

Ho: $P = \frac{1}{2}$ testing whether observations of ground-feeding occur randomly with respect to receding water-levels.
[a]Ho: $P = \frac{1}{2}$ rejected, $p < .001$, critical value = 10.8, df = 1.
[b]Ho: $P = \frac{1}{2}$ rejected, $p < .01$, critical value = 6.6, df = 1.

programme, and to controlled harvesting of returning adult fish.

One of the difficulties of sustaining salmonids in the Columbia River has been high mortality of the juvenile downstream migrants. Newly-hatched salmonids are relatively weak swimmers, and can be killed at water-intake structures or steam–electric power-plants (Page *et al.*, 1978). Fisheries research has been directed at discovering ways to reduce fish-kills by designing water-intake structures with low current-velocities and by conducting field studies to define more accurately the timing and migration pathways travelled by the downstream migrants passing through the Hanford Reach.

Many of the young Salmon that pass downstream through the Hanford Reach originate in upstream tributaries where water temperatures are cooler. These fish move seawards in the spring and summer months. However, the travel-time has in some cases been delayed by a month or more, as a result of impediments imposed by a series of downstream dams (Becker, 1973). Because of the delay, the emigrating fish are exposed to higher summer-time water temperatures for longer periods of time than in pre-dam years. This delay is thought to be detrimental to the survival of young salmonids. The downstream passage of juveniles can be facilitated by the spillage of water over the faces of the dams, but this spillage results in a loss of generating capacity. Ways to enhance fish passage and maintain generating capacity are currently being sought by electrical utilities and state and federal fish-management agencies.

### *Fish Diseases*

Diseases are a cause of fish mortality. The bacterial pathogen *Flexibacter columnaris* is present in the Columbia River, and virulent strains produce a fatal fish-disease (Becker & Fujihara, 1978). The infection seems to be related to elevated water-temperatures, and to the presence of coarse fish (especially suckers, *Catostomus* spp.) that live in the fishes' passage facilities at the dams. Various cuts and bruises experienced by the downstream migrants as they pass through turbines or over dam spillways, also facilitate the transmission of infection by *F. columnaris.*

### *Resident Fish*

Smallmouth Bass (*Micropterus dolomieui*) were introduced to the Columbia River from the eastern US in the years prior to 1940. They now provide a self-sustaining sport fishery of local importance. Spawning is confined to the shallow waters of backwater sloughs (Montgomery *et al.*, 1980). Wide fluctuations in water-levels, manipulated at upstream dams, impede spawning success through exposing nests and eggs to desiccation during periods of low-water flow, and also by stranding juvenile fish in shallow, ephemeral pools where they are vulnerable to predation. Smallmouth Bass are especially vulnerable to sport fishing when they are concentrated in the spawning water. Sport-fishing restrictions are enforced along the Hanford Reach, to protect the spawning Bass from potential over-harvest by sport fishing.

**Table II**

*Fish Species Inhabiting the Hanford Reach of the Columbia River.*

| | |
|---|---|
| *Anadromous Fishes* | |
| Chinook Salmon | *Oncorhynchus tshawytscha* |
| Coho Salmon | *O. kisutch* |
| Sockeye Salmon | *O. nerka* |
| Steelhead Trout | *Salmo gairdneri* |
| *American Shad | *Alosa sapidissima* |
| *Resident Large Fishes* | |
| Bridgelip Sucker | *Catostomus columbianus* |
| Largescale Sucker | *C. macrocheilus* |
| Mountain Whitefish | *Prosopium williamsoni* |
| Chisel-mouth | *Acrocheilus alutaceus* |
| Peamouth | *Mylocheilus caurinus* |
| Northern Squawfish | *Ptychocheilus oregonensis* |
| White Sturgeon | *Acipenser transmontanus* |
| **Carp | *Cyprinus carpio* |
| *Smallmouth Bass | *Micropterus dolomieui* |
| *Largemouth Bass | *M. salmoides* |
| *Black Crappie | *Pomoxis nigromaculatus* |
| *Walleye | *Stizostedion vitreum* |
| *Yellow Perch | *Perca flavescens* |
| *Bluegill | *Lepomis macrochirus* |
| *Channel Catfish | *Ictalurus punctatus* |
| *Bullhead | *I. melas* |
| *Small Fishes* | |
| Threespine Stickleback | *Gasterosteus aculeatas* |
| Sculpin | *Cottus asper* |
| Blacknose Dace | *Rhinichthys atratulus* |
| Longnose Dace | *R. cataractae* |
| Speckled Dace | *R. osculus* |
| Redside Shiner | *Richardsonius balteatus* |
| *Status Unknown* | |
| Cutthroat Trout | *Salmo clarkii* |
| Dolly Varden | *Salvelinus malma* |

* Introduced from eastern/central North America.
** Introduced from Europe.

The White Sturgeon (*Acipenser transmontanus*) is the largest of all fishes in the Hanford Reach. To learn more about their movements, radiotelemetry devices have been attached to adult fish as a way to track individuals in their daily and seasonal travels (Haynes *et al.*, 1981). The information obtained from these studies is useful for formulating management strategies that may be needed to sustain future Sturgeon populations.

The Common Carp (*Cyprinus carpio*) is an inadvertent, alien introduction to the Hanford Reach, and although it is very abundant, there have been no studies made of its life-history and food habits locally, or to find ways to exploit the Carp population as a food-source for people. The Carp population provides a food-source for Great Blue Herons (Rickard *et al.*, 1978), and a few Coyotes have learned to capture Carp trapped in shallow pools created by receding water-levels (Springer, 1980).

Two native salmonids, Cutthroat Trout (*Salmo clarkii*) and Dolly Varden (*Salvelinus malma*), probably became extirpated from the Hanford Reach prior to 1940. Of the sixteen medium- to large-sized resident fish species in the Hanford Reach, nine are introductions from eastern North America or Eurasia that were made prior to 1940 (Table II). Clearly the ability of Man to introduce alien fishes to the Columbia River has altered the species-composition of the Hanford Reach to a great extent.

## Chemical Pollution

At the present time, the Hanford Reach of the Columbia River is relatively free from industrial–urban chemicals. The only sizeable town located on the banks of the mainstream Columbia River upstream from the Hanford Reach is Wenatchee, Washington. There is therefore only a small amount of chemical contamination that is introduced directly into the River before it enters the Hanford Reach (Fig. 1). The closure of eight of the nine Hanford Site plutonium-production reactors in 1972 has essentially terminated the release of radionuclides into the River. During the years of reactor operations, 1944–72, resident fish incorporated radiophosphorus and radiozinc in their tissues, through their foods (Watson & Davis, 1957). Following shutdown of the reactors, these radionuclides disappeared (Cushing *et al.*, 1981). Today, only trace amounts of cobalt-60 and isotopes of plutonium persist in river sediments (Sula, 1980; Beasley *et al.*, 1981).

In the 1960s about 200,000 migrant ducks and geese regularly used the Hanford Reach during the autumn and winter months. Radioactive phosphorus and zinc were detected in 41% of the ducks and geese killed by sports hunters within a 50-miles (80 km) radius of the Hanford Reach (Hanson & Case, 1963). Radiochemical analyses of goose eggs taken from nesting islands in the Hanford Reach in the 1970s, indicated that caesium-137 was the most abundant Man-induced radionuclide in the inner egg contents, and that strontium-90 was the most abundant radionuclide in the calcareous eggshell (Table III). The source of these radionuclides is mostly global fallout from weapons'-testing, rather than Hanford industrial sources (Rickard & Sweany, 1977).

Great Blue Herons (*Ardea herodias*) are colonial-nesting, piscivorous birds that can serve as biological indicators of the presence of Man-induced heavy-metals or radionuclides in their foraging environments (Rickard *et al.*, 1978; Fitzner *et al.*, 1982). Toxic metals, such as lead, cadmium, and mercury, were measured in the nest debris (faeces and fish-scraps) at Heron colonies located at Lake Coeur d'Alene in Idaho, Tacoma in Washington, and the Hanford Reach (Fig. 1). The lowest levels of those metals were measured in debris collected on the Hanford Site (Table IV), indicating the relatively pollution-free environment of the Hanford Reach.

Table III

*Radionuclide Content pCi/kilogram Ash, of Canada Goose Eggs from the Hanford Reach of the Columbia River.*
(Data from Rickard & Sweany, 1977.)

| *Radionuclides* | *Soft Parts* | *Eggshell* |
|---|---|---|
| $^{137}Cs$ | 1,600 | 32 |
| $^{90}Sr$ | 560 | 1,700 |
| $^{65}Zn$ | 430 | 180 |
| $^{54}Mn$ | 140 | ND |
| $^{60}Co$ | 39 | 8 |

ND = not detected

Table IV

*Lead, Cadmium, and Mercury, Contents of Debris Cast from Herons' Nests at Hanford and Tacoma, Washington, and Lake Cœur d'Alene, Idaho, ppm of Dry-weight.*
(Data from Fitzner *et al.*, 1982.)

| | *Tacoma* | *Hanford* | *Cœur d'Alene* |
|---|---|---|---|
| Lead | 29 ± 5.3 | 3.3 ± .35 | 46 ± 7.4 |
| Cadmium | 0.19 ± .020 | .045 ± .040 | 1.8 ± .08 |
| Mercury | 0.17 ± .019 | .10 ± .007 | .28 ± .011 |

n = 6.
± = standard error of mean.

A nesting population of Western Canada Geese on the US Fish and Wildlife Services' Umatilla National Wildlife Refuge, located downstream from the Hanford Reach, has experienced mortality and reduced reproductive success through ingestion of wheat grains and seedlings treated with a chemical pesticide (heptachlor) applied as a control for wireworms on private lands (Blus *et al.*, 1979). In the past 10 years, the reproductive success of nesting Geese along the Hanford Reach has remained stable, indicating that toxic chemicals are not affecting the reproductive success of those at Hanford (DeWaard, 1981; Fitzner & Rickard, 1983). Nevertheless, toxic chemicals are being introduced into the riverine environment by steadily-increasing industrial, agricultural, and urban, uses. Environmental toxicity represents a growing new field for wildlife research (Kendall, 1982).

## Summary

The Hanford Reach of the Columbia River has experienced a great deal of human-imposed environmental change within the past 40 years, as has much of the adjacent land. The major disturbances have been from hydroelectric dams' construction and an intensive expansion of irrigated agriculture. A notable exception to the steady expansion of agriculture and dam-building has been the 1,400 km$^2$ Hanford Site, which was established in 1943. Today, the Hanford Site consists mostly of undeveloped land that still supports native vegetation. It is free from agricultural practices, and has also been essentially free from livestock grazing and the shooting of animal wildlife. This conservative land-use has favoured populations of native wildlife that use the riverine habitats of the Hanford Reach of the Columbia River—e.g. Mule Deer, Canada Goose, and Great Blue Heron, are notable instances.

The Hanford Reach supports the only mainstem Chinook Salmon spawning habitat on the Columbia River. This population is maintained by a combination of natural spawning and artificial propagation in concert with a regulated harvest of returning adults. Numbers of mainstem spawning Salmon have increased markedly in the past 10 years, and this has attracted increasing numbers of wintering Bald Eagles to the Hanford Reach.

With the shutdown in 1972 of plutonium-production reactors located on the Hanford Reach, the short-lived radionuclides of $^{32}$P and $^{65}$Zn, that once were abundant in Columbia River water and biota, have disappeared by radiodecay and through river-flushing actions. Barely detectable amounts of $^{239}$Pu (half-life 24,000 years) of Hanford Site origin persist in the sediments accumulated above the first dam downstream from the Hanford Site. Chemical pollutants in the riverine environment here can be expected from two future sources: industrial development along the Columbia River upstream from the Hanford Site, and increases in the uses of agricultural chemicals with runoff into the Columbia River.

## References


Ball, I.J., Bowhay, E.L. & Yocum, C.E. (1982). *Ecology and Management of the Western Canada Goose in Washington.* Washington Dept of Game, Biol. Bull. No. 17, vii + 67 pp.

Beasley, T.M., Ball, L.A. & Andrews, J.E. (1981). Hanford-derived plutonium in Columbia River sediments. *Science*, **214**, pp. 913–5.

Becker, C.D. (1973). Columbia River thermal effects study: Reactor effluent problems. *J. Water Pollution Control Federation*, **45**(5), pp. 850–69.

Becker, C.D. & Fujihara, M.P. (1978). The bacterial pathogen, *Flexibacter columnaris*, and its epizootiology among Columbia River fish. *American Fisheries Society*, Monograph No. 2, 92 pp.

Blus, L.J., Henny, C.J., Lenhart, D.J. & Cromartie, E. (1979). Effects of heptachlor-treated cereal grains on Canada Geese in the Columbia Basin. Pp. 105–16 in *Management and Biology of Pacific Flyway Geese* (Eds R.L. Jarvis & J.C. Bartonek). Oregon State University Bookstore, Corvallis, Oregon, USA: 346 pp.

Books, G.G. (in press). Avian interactions with mid-Columbia River water-level fluctuations. *Northwest Science*.

Conover, M.R., Thompson B.C., Fitzner, R.E. & Miller, D.E. (1979). Increasing populations of Ring-billed and California Gulls in Washington State. *Western Birds*, **10**, pp. 31–6.

Cushing, C.E., Watson, D.G., Scott, A.J. & Gurtisen, J.M. (1981). Decrease of radionuclides in Columbia River biota following the closure of Hanford reactors. *Health Physics*, **41**, pp. 59–67.

Daubenmire, R. (1970). Steppe vegetation of Washington. *Wash. State Agric. Expt. Sta. Tech. Bull.*, **60**, 131 pp.

Davis, J.J. & Foster, R.F. (1958). Bioaccumulation of radioisotopes through food-chains. *Ecology*, **39**, pp. 530–5.

DeWaard, B.D. (1981). *Reproduction and Ecology of Canada Geese on the Hanford Reservation, 1953–1980.* MS thesis, Washington State University, Pullman, Washington, USA: 87 pp.

Eberhardt, L.E., Hanson, E.E. & Cadwell, L.L. (1984). Movement and activity patterns of Mule Deer in the sagebrush-steppe region. *J. Mammalogy*, **65**, pp. 404–9.

Fitzner, R.E. & Hanson, W.C. (1979). A congregation of wintering Bald Eagles. *Condor*, **81**, pp. 311–3.

Fitzner, R.E., Rickard, W.H. & Hinds, W.T. (1982). Excrement from Heron colonies for environmental assessment of toxic elements. *Env. Monit. and Assessment*, **1**, pp. 383–6.

Fitzner, R.E. & Rickard, W.H. (1983). Canada Goose nesting performance along the Hanford Reach of the Columbia River, 1971–1981. *Northwest Science*, **57**, pp. 267–72.

Foster, R.F. (1972). The Hanford story and its contributions of radioactivity to Columbia River water. Chapter 1 in *The Columbia River Estuary and Adjacent Ocean Waters Bioenvironmental Studies* (Eds A.T. Pruter & D.L. Alverson). University of Washington Press, Seattle, Washington, USA: xiii + 868 pp.

Hanson, W.C. (1960). Accumulation of radioisotopes from fallout by terrestrial animals at Hanford, Washington. *Northwest Science*, **34**, pp. 89–98.

Hanson, W.C. & Case, A.C. (1963). A method of measuring waterfowl dispersion utilizing phosphorus-32 and zinc-65. Pp. 451–4 in *Radioecology: Proceedings of the First National Symposium in Radioecology held at Colorado State University, Fort Collins, Colorado* (Eds V. Schultz & A.W. Klement). (10–15 September 1961.) Rheinhold Publishing Corporation, New York, NY, USA: xvii + 746 pp.

Hanson, W.C. & Eberhardt, L.L. (1971). A Columbia River Canada Goose population. *Wildl. Monogr.*, No. 28, 61 pp.

Haynes, J.M., Gray, R.H. & Montgomery, J.C. (1981). Diet and seasonal movements of sturgeon (*Acipenser transmontanus*) in the mid-Columbia River. *Fish Bull.*, **79**, pp. 367–70.

Hedlund, J.D. (1975). Tagging Mule Deer fawns in south-central Washington. *Northwest Science*, **49**, pp. 253–60.

Henderson, C. & Foster, R.F. (1957). Studies of Smallmouth Bass (*Micropterus dolomieui*) in the Columbia River near Richland, Washington. *Trans. Amer. Fish. Soc.*, **86**, pp. 112–27.

Kendall, R.J. (1982). Wildlife toxicology. *Env. Sci. and Tech.*, **16**, pp. 448A–53A.

Montgomery, J.C., Fickeisen, D.H. & Becker, C.D. (1980). Factors influencing Smallmouth Bass production in the Hanford area, Columbia River. *Northwest Science*, **54**(4), pp. 296–305.

Page, T.L., Neitzel, D.A. & Gray, R.H. (1978). Comparative fish impingement at two adjacent water intakes on the mid-Columbia River. Pp. 257–66 in *Fourth National Workshop on Entrainment and Impingement* (Ed. L.D. Jensen). Ecological Analysts, Melville, New York, NY, USA: xx + 424 pp.

Rickard, W.H. & Sweany, H.A. (1977). Radionuclides in Canada Goose eggs. Pp. 623–7 in *Biological Implications of Metals in the Environment* (Eds R.E. Wildung & H. Drucker). Conf-750929, TIC, Oak Ridge, Tennessee, USA: ix + 682 pp.

Rickard, W.H., Hedlund, J.D. & Schreckhise, R.G. (1978). Rejecta cast from heron nests as an indicator of food-chain contamination. *The Auk*, **95**, pp. 425–7.

Rickard, W.H., Hanson, W.C. & Fitzner, R.E. (1982). The non-fisheries biotic resources of the Hanford Reach of the Columbia River. *Northwest Science*, **56**, pp. 62–76.

Sauer, R.H. & Leder, J.E. (in press). The status of Yellowcress in Washington. *Northwest Science* (accepted).

Sauer, R.H., Mastrogiuseppe, J. & Smookler, R. (1978). *Astragalus columbianus*: Rediscovery of an 'extinct' species. *Brittonia*, **31**, pp. 261–4.

SERVHEEN, C.W. (1975). *Ecology of Wintering Bald Eagles on the Skagit River, Washington.* M.S. thesis, University of Washington, Seattle, Washington, USA: 96 pp.

SPRINGER, J.T. (1980). Fishing behavior of Coyotes on the Columbia River. *J. Mammalogy*, 61, pp 373–4.

STALMASTER, M.V., NEWMAN, J.R. & HANSEN, A.J. (1979). Population dynamics of wintering Bald Eagles on the Nooksack River, Washington. *Northwest Science*, 53, pp. 126–31.

STEIGERS, W.D. & FLINDERS, J.T. (1980). Mortality of Mule Deer fawns in south-central Washington. *J. Wildlife Manage.*, 44, pp. 381–8.

SULA, M.J. (1980). *Radiological Survey of Exposed Shorelines and Islands of the Columbia River between Vernita and the Snake River Confluence.* (PNL-3127.) Battelle Pacific Northwest Laboratory, Richland, Washington, USA: 42 pp. + appendix.

WATSON, D.G. (1970). *Fall Chinook Salmon Spawning in the Columbia River Near Hanford, 1947–1979.* (BNWL-1515.) Battelle Pacific Northwest Laboratory, Richland, Washington, USA: 40 pp. + appendix.

WATSON, D.G. & DAVIS, J.J. (1957). *Concentration of Radioisotopes in Columbia River Whitefish in the Vicinity of the Hanford Atomic Products Operation, Richland, Washington.* (HW-4852.) Hanford Atomic Products Operations, Richland, Washington, USA: 136 pp. + appendix.